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Literature Review on Cold-Formed Steel Lipped Channel Beams About Shear Behaviour

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ABSTRACT

Cold-formed steels (CFS) or light gauge steels (LGS) are steel sections created through processes without heat application, such as roll forming or press-braking. In the past few decades, the utilization of CFS as a structural material has expanded due to its advantages over the other materials used in the construction industry, consequently increasing the number of studies conducted by many researchers. CFS studies have focused on many research areas, including designing and analyzing members and systems, connections, sustainability, residual stresses and post-fire data. Cold-formed high strength steel members are increasingly used as primary load bearing components in low-rise buildings. Lipped channel beam (LCB) is one of the most commonly used flexural members. International design codes – European standards (EN1993-1-3), North American standards (AISI S100) and Australian and New-Zealand standards (AS/NZS 4600) – contain shear design provisions to estimate the shear strength of CFS sections. The literatures were collected based on the previous investigations in the field of shear behaviour and design of ultra-high strength cold-formed steel lipped channel beams.

KEYWORDS: **Cold-formed steel, Lipped channel beams, Shear capacity, Stiffener**

I. INTRODUCTION

Literature review

Poologanathan Keerthan, Mahen Mahendran – Experimental investigation and design of lipped channel beams in shear – 2015

In this experimental study a series of primarily shear tests of simply supported Lipped Channel Beams (LCBs) subjected to a mid-span load was conducted. Two LCB sections were bolted back-to-back using three 30 mm thick T-shaped stiffeners between them and twelve 10 mm full height web side plates on both sides which were located at the end supports and the loading in order to eliminate any torsional loading of test beams and possible web crippling. In order to simulate a shear condition, relatively short test beams were selected based on suitable aspect ratios of 1.0 and 1.5. They were made of three thicknesses of 1.50,1.90 and 1.95 mm and two steel grades of G250 and G450. LCBs flanges were restrained by angle straps to eliminate flange distortion due to the presence of unbalanced shear flows and distortional buckling. In order to prevent twisting of the section, the point load and simply supported boundary conditions have to be applied at the shear centre of the section. They found that full web side plates were provided on both sides of beams to simulate simply supported conditions, which is sufficient to develop post-buckling strength in web elements due to tension field action. Test results showed that there was about **9 to 20% reduction in the shear capacity of LCBs** when flange straps were not used. Combined bending and shear actions can influence the failures in longer, low grade steel beams, i.e., beams with a higher aspect ratio and a lower flange yield stress. Lower bound DSM equations are proposed in this paper to predict the shear capacities of LCBs and thus ensure a safe design of LCBs.

Poologanathan Keerthan, Mahen Mahendran – Improved shear design rules for lipped channel beams with web openings – 2014

The shear behaviour of these LCBs with web openings is complicated and their shear capacities are reduced by the presence of web openings. Eiler proposed shear strength equations have been adopted in AISI S100 and AS/NZS 4600 design standards for cold-formed steel structures. Hence a detailed numerical study was undertaken to investigate the shear behaviour and strength of LCBs with unreinforced circular web openings for the aspect ratio 1.0 and 1.5. The developed non-linear finite element model was able to predict the shear capacities of LCBs with web openings and associated deformations and failure modes with very good accuracy. Test results showed that there was about **3 to 11% reduction in the shear capacity of LCBs with web openings,** when flange straps were not used. Numerical and experimental studies show that AS/NZS 4600 design equations are conservative for LCB sections with small web openings while they are unconservative for LCB sections with large web openings.

Perampalam Gatheshgar, Marina Bock, Dilanka Chandrasiri, Thadshajini Suntharaligam – assessment of Eurocode shear design provisions for cold-formed steel sections - 2023

Cold-formed steel sections are widely used which are prone to shear failure in short span applications. Therefore, accurate shear strength estimation is essential for the design. International design codes – European standards (EN1993-1-3), North American standards (AISI S100) and Australian and New-Zealand standards (AS/NZS 4600) – contain shear design provisions to estimate the shear strength of CFS sections. Direct strength method (DSM) approach proposed by Pham and Hancock has been adopted in AISI S100 and AS/NZS 4600. Keerthan and Mahendran modified shear buckling coefficients considering level of restraint has been included in the appendix D3 of AS/NZS 4600. EN1993-1-3 indicates that shear buckling strength f_{bv} is influenced by the stiffening conditions:

1. Web with stiffening at the supports referred to attachment of cleat plates or web side plates to prevent the web crippling and safely resisting the support reaction.

2. Web without stiffening at the support.

It can be observed that the current shear design provisions in EN1993-1-3 provide overly conservative shear strength predictions as the average of $V_{test}/V_{EN1993-1-3}$ equals 1.47 with coefficient of variation equals 0.141 for hollow flange sections. Also, all the experiment to EN1993-1-3 prediction ratios were higher than unity for lipped channel sections. The shear design provisions in EN1993-1-3 do not consider, the level of restraint at the web-flange juncture, cross-sectional shape and aspect ratio. Therefore, improved design provisions may be achieved by including those effects. The proposed shear design provisions are limited to CFS sections without longitudinal stiffeners and web with stiffening at the support condition.

Cao Hung Pham, Gregory J. Hancock - Numerical investigation of longitudinally stiffened web channels predominantly in shear – 2015

In practice, the web is stiffened by adding longitudinal intermediate stiffeners. These stiffeners may improve the shear capacities of the channels. Recently, the Direct Strength Method (DSM) of design of cold-formed sections has been extended in the NAS S100: 2012 to include shear based on research by the authors. To extend the range to larger intermediate stiffeners, six different types of stiffened web channel sections were tested along with an additional reference plain section. All tests were conducted with four straps screwed on each top and bottom flanges adjacent to the loading points and supports. These straps provide torsion/distortion restraints which may enhance the shear capacities of the sections. As the shear strength is improved by the large web stiffeners, the effect of bending becomes important. The use of two stiffened channel sections which were connected to the test beam, used to prevent bearing failure at the loading point and supports. The stiffened web channels (SWC) with two indents (5 and 15 mm) and three web stiffener depths of 20 mm, 40 mm and 90 mm were chosen for the longitudinal web stiffener dimensions. 5 mm indent is inclined at 45degree due to the minimum gap required between two bends and 15 mm indent are folded perpendicularly to form a rectangular web stiffener. SWC sections were modelled by using the 4-node shell elements with reduced integration(S4R). Quadrilateral element mesh was used. To simulate a set of simple supports “CONN3D2” connector elements were used to connect bearing plates to the centre of the half round. For bolt simulation, “tie” constraints were used to model contacts between the specimens and rigs. As a result, the test points of the SWC lie below the DSM shear curve with tension field action (TFA). The reason is increase in the shear capacity relative to the bending capacity. The test failures were observed mainly in the combined bending and shear modes. The test and FEM results are plotted against the DSM interaction curves between bending and shear where the interaction is found to be significant.

CONCLUSION

Based on the literature review of the experimental, numerical and theoretical studies, though many studies have been discussed based on the investigations in the field of shear behaviour and design of ultra-high strength cold-formed steel lipped channel beams. When flange straps were not used **9 to 20% reduction in the shear capacity of LCBs without web openings** and **3 to 11% reduction in the shear capacity of LCBs with web openings.** Combined bending and shear actions can influence the failures in longer, low grade steel beams, i.e., beams with a higher aspect ratio and a lower flange yield stress. Shear design provisions have been suggested for updates based on extensive research studies on the shear response of CFS sections.

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